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Transesterification of Castor Oil Catalyzed by Liquid Enzymes: Optimization of Reaction Conditions

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INTRODUCTION

- Biodiesel → option to assure a sustainable supply of fuel.

→ transesterification of triglycerides TAG) or esterification of free fatty acids (FFA).
→ mixture of fatty acid methyl esters (FAME).

- Enzymes → promising alternative biocatalyst.
  → no soap formation, esterify both TAG and FFA, produce a high quality glycerol.
  → work under mild reaction conditions.

OBJECTIVES

- Biodiesel production from castor oil, using a liquid lipase catalyst (Eversa Transform).
- Evaluation of the effect of temperature, water content, enzyme content, and alcohol-to-oil molar ratio on product yield and quality.
- Development of a reaction equilibrium model from the optimal conditions using Aspen Plus.

MATERIALS AND METHODS

- Transesterification reactions performed for 8 hours, at 750 rpm.
- Stepwise additions of methanol at 2 hours interval.
- Reaction samples analyzed in a HPLC system.

Table 1: Experimental conditions evaluated

Factor	Coefficient	Level		
		Low	Center	High
Temperature (°C)	X_1	35.0	40.0	45.0
Alcohol-to-oil molar ratio	X_2	4.5	6.0	7.5
Enzyme content (wt%)	X_3	2.0	5.0	10.0
Water content (wt%)	X_4	0.0	5.0	10.0

- Effect of the parameters analyzed using response surface methodology (RSM) implemented in Statistica v.13: 4 factors at 3 levels employed, requiring 27 experiments.
- Process simulated by means of Aspen Plus v8.8, based on the optimal reaction conditions.

RESULTS AND DISCUSSION

- Results evaluated in terms of FAME yield and FFA content
- The effect of the factors in the biodiesel yield resulted in a second-order model:

$$\text{Yield}_{\text{FAME}} = -1.4327 - 0.0147X_1 + 0.4530X_2 + 0.2704X_3 + 0.1710X_4 - 0.0018X_1X_2 - 0.0016X_1X_3 + 0.0015X_1X_4 - 0.0070X_2X_3 - 0.0159X_3X_4 + 0.0003X_1^2 - 0.0279X_2^2 - 0.0049X_3^2 - 0.0104X_4^2$$

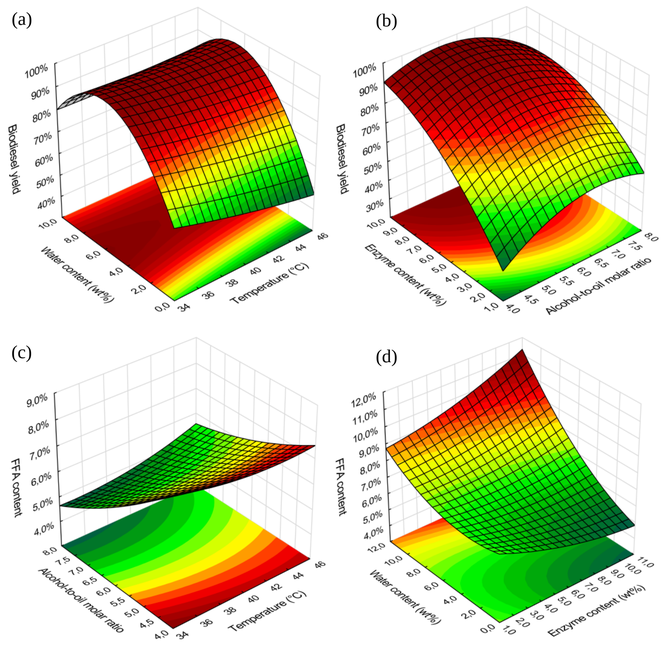

Figure 1: Response surface plots. (a),(b) FAME yield and (c),(d) FFA content as function of the process variables.

- Temperature had the least influence on FAME yield.
- Small addition of water increases the catalytic efficiency.
- High addition of water increases the production of FFA.
- Lower amount of MeOH leads to incomplete reaction.
- Higher amount of the MeOH inhibits enzyme activity.

- Optimal conditions obtained at 35°C, 6.0 alcohol-to-oil molar ratio, and 5.0 wt% of enzyme and water contents.

Table 2: Comparison between the experimental and simulated composition

Component	Molar composition [%]	
	Experimental	Simulated
Triricinolein	0.00	0.00
Diricinolein	0.00	0.00
Monoricinolein	0.38	0.00
Methyl ricinoleate	21.66	22.99
Ricinoleic acid	1.43	0.00
Methanol	31.02	29.67
Glycerol	7.28	7.67

- Difference could be due to an insufficient reaction time necessary to reach the equilibrium conditions.

CONCLUSIONS

- Transesterification at 35 °C, with 5 wt% of enzymes, 5 wt% of water, and 6.0 alcohol-to-oil molar ratio resulted in the best combination of reaction conditions, with the biodiesel yield of about 94 %.

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